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THE EFFECT OF THREE CRITERIA AIR CONTAMINANTS (PM_{10}, NO_2, SO_2) ON RESPIRATORY DISEASES AND MORTALITY IN ILAM

ELAHE ZALLAGHI [1*], MEHDI NOURZADEH HADDAD[2], ZAHRA SOLEIMANI[3]

1:Lecturer at applied science training center, Ahvaz municipality, Ahvaz,Iran ,Young Researchers and Elite club, Ahvaz Branch, Islamic Azad University, Ahvaz, Iran.

2:Assistant professor, Department of agriculture, Payame Noor university,P.O.BOX,19395-3697,Tehran,Iran.

3:Department of Environmental Health Engineering, Aradan School of Paramedicine and Public Health AND Students Research Committee, Semnan University of Medical Sciences, Semnan, Iran

***Corresponding Author:** elahezallaghi@yahoo.com

ABSTRACT

Geographical location of Ilam and its being surrounded by altitudes in north, and southwest-northwest route of general currents of air along with the influence of dusty air flows from Iraq in some special times of the year particularly in summer and winter have increased the rate of dust and air pollution in the city of Ilam. About 30 to 40% of asthma cases and 20 to 30% of all respiratory diseases can be associated with air pollution. The present study, which is a cross-sectional epidemiological study, aims to investigate the health effects of three criteria air contaminants (PM_{10}, NO_2, SO_2) in Ilam located in southwestern part of Iran. The results of the measurement in 2013 showed that the annual average concentration of PM_{10}, NO_2, and SO_2 contaminants in Ilam was equal to 300.55, 92.41, and 30.43 $\mu g/m^3$, respectively. The maximum annual concentration of PM_{10} was equal to 3202 $\mu g/m^3$ that showed up in summer and the concentrations of 194.1 and 67.5 $\mu g/m^3$ have been respectively recorded for No_2 and SO_2 in winter. Estimating epidemiological indices attributed to PM_{10} contaminant showed that the cumulative number of deaths and respiratory diseases in 2013 in Ilamwas estimated as average relative risk and the rate of base incidence was 45 and 605 people respectively. In the central level of relative risk, the cumulative number of chronic obstructive pulmonary disease attributed to NO_2in 2013 in Ilam was estimated to be 15 increase of NO_2 at concentrations of 40-70 µg had a uniform increasing trend and the concentration above 80 µg it had a sudden increase. The results showed that the indices of relative risk, percentage of attributed ratio, and the cumulative number of cases attributed to NO_2 for the chronic disease of obstructive pulmonary were1.0044, 0.67% and 3 people respectively in 2013in Ilam. For every 10 µg/m^3increase in the concentration of PM_{10}, the rate of respirator mortality risk and the hospital admissions increased 1.2% and .08%, respectively. Moreover, for every 10 µg/m^3increase in the concentration of SO_2, the rate of respiratory death risk and the chronic obstructive pulmonary diseaseincreased 1% and 0.44%, respectively.

Keywords: Criteria contaminants, epidemiological index, relative risk, respiratory disease, Ilam

INTRODUCTION

Urbanization, excessive development of industries in residential areas, the loss of green space due to the use o land for housing and the excessive growth of population which is followed by the increasing consumption of fossil fuels have caused the increasing pollution of breathing air [1]. Ever year millions of people lose their lives or are suffering from the serious health effects of air pollution mainly including respiratory diseases, asthma, chronic lung diseases, cardiovascular diseases, and lung cancer [2]. It is estimated that 3 million people die every year due to air pollution which is about 5% of the whole 55 million deaths that occurs in the world each year for various reasons. Many studies have shown the direct relationship between mortality and concentration of suspended particles with the diameter of less than 10 µm in PM_{10} contaminant available in the air. About 30 to 40% of the asthma disease and 20 to 30% of total respiratory diseases can be associated with air pollution. Some studies in Sao Paulo, Brazil have shown that the increase of NO_2 concentration by 75 µm/m^3 can be associated with 30% increase of deaths due to respiratory diseases in children younger than five years [3]. The effects of air pollution on human beings are interpreted based on epidemiological studies and toxicology research. Epidemiological studies include the observed effects of contaminants on people who naturally have been exposed to them. Epidemiological studiesdetermine the quality of air pollution and its effect on public health [4, 5]. Five types of air pollutants are known as main criteria air pollutants which cause over 90% of the air pollution. They include carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), and suspended particles (TSP, PM_{10}, PM_{25}) [6, 7, 8].

1.1. Nitrogen Oxides (NO_x)

Seven oxides have been identified for nitrogen including NO, NO_2, NO_3, N_2O, N_2O_3, N_2O_4, and N_2O_5. Among the cited oxides NO and $NO_2$are important in terms of contamination [9, 10]. Nitrogen dioxide (NO_2) is an inflammable maroon gas with a nasty irritating odor. It is also relatively toxic and extremely corrosive.

1.2. Sulfur Oxides (SO_x)

Among the air pollutants, sulfur oxides have devoted the widest and the most studied to themselves. They include six different gaseous compounds as sulfur monoxide (SO), sulfur dioxide (SO_2), sulfur trioxide (SO_3), sulfur tetroxide (SO_4),sulfursesquioxide(S_2O_3), and sulfur heptoxide (S_2O_7). In air pollution studies, sulfur dioxide (SO_2) and sulfur trioxide (SO_3) are the most important ones [11]. Sulfur dioxide (SO_2) is a colorless, non-explosive gas with suffocating odor and almost twice as heavy as air. It is estimated that SO_2remains in the air about 2 to 4 days in average. More than 80% of sulfur oxides are produced by human being during the combustion of fossil fuels of fixed contaminant sources. Power plants share about 85% and cars share only 2% of this amount. Oil refineries, steel mines, copper smelting factories, and cement factories are among the non-combustion sources producing sulfur oxides [12].

1.3. Suspended Particles (TSP, PM_{10}, $PM_{2.5}$)

Suspended particles refer to those scattered solid or liquid substances that are larger than a molecule diameter (0.0002μm) and smaller than 500μm. These materials as a branch of pollutants are quite various and complex, and their size and chemical composition such as their concentration in the air are some of their important characteristics [13].

1.4. The Effect of Criteria Contaminants on Human Health

1.4.1. Nitrogen Dioxide

A. Groups at risk (those with the highest vulnerability level)

1. Children and adults with chronic lung diseases such as asthma
2. Short-term exposure in children can lead to the increased risk of lung disease development [14].

B. Complications

1. Long-term complications such as reduction of respiratory system resistance to infections and diseases such as influenza.

2. Lower respiratory tract irritation and stimulation
3. Severe respiratory diseases in children
4. Lasting structural changes in respiratory tract in the long term
5. Reduction of breathing depth and shortness of breath
6. Sever coughing and wheezing [15]

1.4.2. Sulfur Dioxide

A. Groups at risk (those with the highest vulnerability level)

1. Children and adults with asthma, bronchitis, or emphysema
2. Elderly
3. Total population that stimulates respiratory tract
4. Patients with cardiovascular diseases and chronic respiratory diseases
5. Ordinary people with a lot of activities in free environment [16]

B. Complications

1. Narrowing of breathing airways (Bronco constriction)
2. Bronco spasm
3. Sever cough
4. Eye and respiratory tract irritation
5. Reduction of breathing efficiency and shortness of breath
6. Shortness of breath and reductionof breathing depth
7. Aggravation of respiratory and cardiovascular complications [17]

1.4.3. Sustained Particles

A. (Groups at risk (those with the highest vulnerability level)

1. People with respiratory and cardiovascular diseases such as patients with asthma, chronic lung diseases, and ischemic heart diseases which cause early death and require special cares.
2. Sustained particles cause early death in the elderly and they need special cares.
3. Sustained particles in children and patients with lung diseases cause lack of deep breathing and sever cough [18]

B. Complications

1. Coughing
2. Adverse effects on chest
3. Effects on defense mechanisms
4. Cancer effects
5. Intensity of ischemic heart diseases
6. Reduction of breathing efficiency and shortness of breath
7. Difficulty in deep breathing
8. Rapid breathing with little breath depth
9. Hypersensitivity against respiratory infections

10. Severity of chronic lung diseases such as bronchitis exacerbation [19]

MATERIALS AND METHODS

The present research, which is a cross-sectional epidemiological study, aims to quantify and investigate the health effects of three criteria air contaminants (PM_{10}, NO_2, SO_2) in Ilam located in southwestern part of Iran. The research contains three parts: the first step is the measurement of PM_{10}using Beta ray atomic analysis and sampling and So2 and NO_2 pollutants via Fourier transform infrared stereoscopy (FTIR), Chemiluminescence within one solar year (October 2012 to June 2013) in two seasons of summer and winter. The secondstep is the estimation of epideomological indices: attributed proportion (AP): a part of health outcome that can be associated with exposure to a particular population (assuming a probable relationship between exposure and health outcome without any destructive effect on the relationship) over a specific period of time. This component is calculated via the following formula (20).

$$AP = SUM \{[RR (c) -1] p (c)\} / SUM [RR (c) p (c)]$$

Where:

RR(c): relative risk of health outcome in group c or the considered group

P(c): population ratio of group c or considered group

Relative risk of selected health outcomes can be calculated via exposure-response functions (20).

$$RR = \frac{\text{Probability of event when exposed}}{\text{probability of event when non - exposed}}$$

Knowing the basic incidence of selective health outcome (I) in the target population, the attributed proportion to population exposure (or the number of cases per population unit) (IE) can be calculated as the following (20):

$$IE = I \times AP$$

In a population of N size, this amount can be converted to the number of estimated cases attributed to exposure (NE):

$$N \times NE = IE$$

Instead of determining the basic incidence of health outcomes, user can use local statistics. As a result, the incidence of outcomes in the population that is not at the risk of exposure (INE) can be estimated (20):

$$INE = I – IE = 1 \times (1 – AP)$$

In addition to total attributed cases, the distribution of attributed cases can be estimated based on the intervals of contaminant concentration. Knowing the relative risk at a special level of pollutant concentration and the rate of incidence in non-exposed population, the rate of additional incidence (I+ (c)) and the number of additional cases (N+(c))in a contact group c will be calculated through the following relations:

I+(c) = (RR(c-1))P(c) × INE

All of the above formulae are based on the assumption that the estimation used in this analysis has been controlled in terms of all possible destructive factors. By placing confidence intervals of relative risk estimation in the formula, it is possible to determine high and low extents of attributed component estimation and the range of attributed cases to the expected exposure.However, in practice, the uncertainty of the effect (and the range of estimated effects) are greater due to exposure assessment errors and non-statistical uncertainties of concentration-response function.

Third step: data analysis: in this step, Excel and SPSS software were used to draw the diagrams and Kolmogorov-Smirnov Test was used to assess the normal distribution of data.

2.1. Introducing the Studied Area (Ilam)

Ilam Town is located in the northwestern part of Ilam Province and is bordered with Ivan, Malekshahi, Shirvan, Chadaval, Darreshahr, and Mehran. Iran is limited to Iraq in west. Its population is 213579 people.

Figure (1): a view of the studied area, Ilam

Findings and Results

3.1. The results of criteria air contaminants measurement in Ilam and estimation of epidemiological indices attributed to the contaminants in percentage and the number of cases of each outcome

Table (1): Concentrations of PM_{10}, NO_2, and SO2 in μg/m^3 (Ilam, 2013)

Ilam Contaminant SO_2	Ilam Contaminant NO_2	Ilam Contaminant PM_{10}	City–Contaminant Parameter
30.43	92.41	330.55	Annual average concentration
28.32	77.96	392.76	Average concentration in summer
32.54	105.78	263	Average concentration in winter
67.5	194.1	3202	Maximum annual concentration

33.52	**130.13**	**3202**	**Maximum concentration in summer**
67.5	**194.1**	**1351**	**Maximum concentration in winter**

The results of the measurement in 2013 showed that the annual average concentration of PM_{10}, NO_2, and SO_2 contaminants for Ilam was 330.55, 92.41, and 30.43 μg/m^3, respectively. Moreover, the average concentration of PM_{10}, NO_2, and SO_2 contaminants in the summer was 392.76, 77.96, and 28.32μg/m^3, respectively and the results of PM_{10}, NO_2, and SO_2contaminants in the winter were 263, 105.78, and 32.54 μg/m^3. Maximum annual concentration of PM_{10} was 3202 μg/m^3which occurred in the summer and the maximum annual concentration of NO_2 and So_2 was 194.1 and 67.5 μg/m^3 which occurred in the winter.

Table (2): Estimation of relative risk, attributed component, and attributed cases to $PM_{10}$for the deaths resulting from respiratory diseases in Ilam in 2013 (BI=66)

Cumulative number of cases (persons)	Attributed component (%)	Relative risk (average)	Epidemiological Index / Estimation
31/7	**10/6303**	1/008	**Low level**
45/2	15/1408	1/012	**Middle level**
105/9	35/4895	1/037	**High level**

Table (3): Estimation of relative risk, attributed component, and attributed cases to PM_{10} for the respiratory patients in Ilam in 2013 (BI=1260)

Cumulative number of cases (persons)	Attributed component (%)	Relative risk (high)	Epidemiological Index / Estimation
379/4	**6/6615**	1/0048	**Low level**
605/4	**10/6303**	1/008	**Middle level**
813	**14/2755**	1/0112	**High level**

Epidemiological indices estimation attributed to PM_{10} contaminant according to tables 2 and 3 showed that the cumulative number of respiratory deaths and diseases in 2013 in Ilam in the estimation of middle extent of relative risk and basic incidence rate were respectively 45 and 605 persons. Moreover, the results showed that at high relative risk, the cumulative number of respiratory deaths and respiratory diseases were 106 and 813 persons, respectively.

Table (4): Estimation of relative risk, attributed component, and attributed cases to NO_2 for patients with chronic obstructive pulmonary disease (COPD) in Ilam in 2013 (BI=101.4)

Cumulative number of cases (persons)	Attributed component (%)	Relative risk (average)	Epidemiological Index / Estimation
1/7	0/3652	1/0004	Low level
15/4	3/3651	1/0038	Middle level
36/3	7/9309	1/0094	High level

As shown in Table (4), at central level of relative risk, cumulative number ofchronic obstructive pulmonary disease attributed to NO_2 pollutant in 2013 in Ilam, was estimated to be 15 persons. At low and high levels of relative risk, the cumulative number of chronic obstructive pulmonary disease was 2 and 36 persons, respectively.

Table 5: Estimation of relative risk, attributed component, and attributed cases to SO_2 for the deaths resulting from respiratory diseases in Ilam in 2013 (BI=66)

Cumulative number of cases (persons)	Attributed component (%)	Relative risk (low)	Epidemiological Index / Estimation
2/8	0/9218	1/006	Low level
4/6	1/5270	1/01	Middle level
6/6	2/1548	1/014	High level

Table (6): Estimation of relative risk, attributed component, and attributed cases to SO_2 for patients with chronic obstructive pulmonary disease (COPD) in Ilam in 2013 (BI=101.4)

Cumulative number of cases (persons)	Attributed component (%)	Relative risk (low)	Epidemiological Index / Estimation
0/00	0/000	1	Low level
3/1	0/6777	1/0044	Middle level
7/7	1/6771	1/011	High level

The results of table (5) showed that according to the component percentage complied with three estimated levels of relative risk, cumulative number of respiratory deaths attributed to SO_2 was 5 persons (3 persons at low relative risk (rr= 1.006) and 7 persons at high relative risk (rr=1.014)).

The results of table (6) showed that relative risk, attributed ratio percentage, and cumulative number of cases attributed to sulfur dioxide for chronic obstructive pulmonary diseasewere 1.0044, 0.67%, and 3 persons respectively in 2013 in Ilam.

3.2. Quantification Results of Epidemiological Indices (Displaying Number of Outcomes against Contaminants Concentration for Relative Risk Levels) in Ilam in 2013

Diagrams 1 to 5 are drawn based on the cumulative number of a health outcome affected by relative contaminant concentration in quantification discussion. The features have illustrated the number of cases at high, middle, and low levels of relative risk. Therefore, there are three curves in each diagram and the middle curve corresponds to the central relative risk.

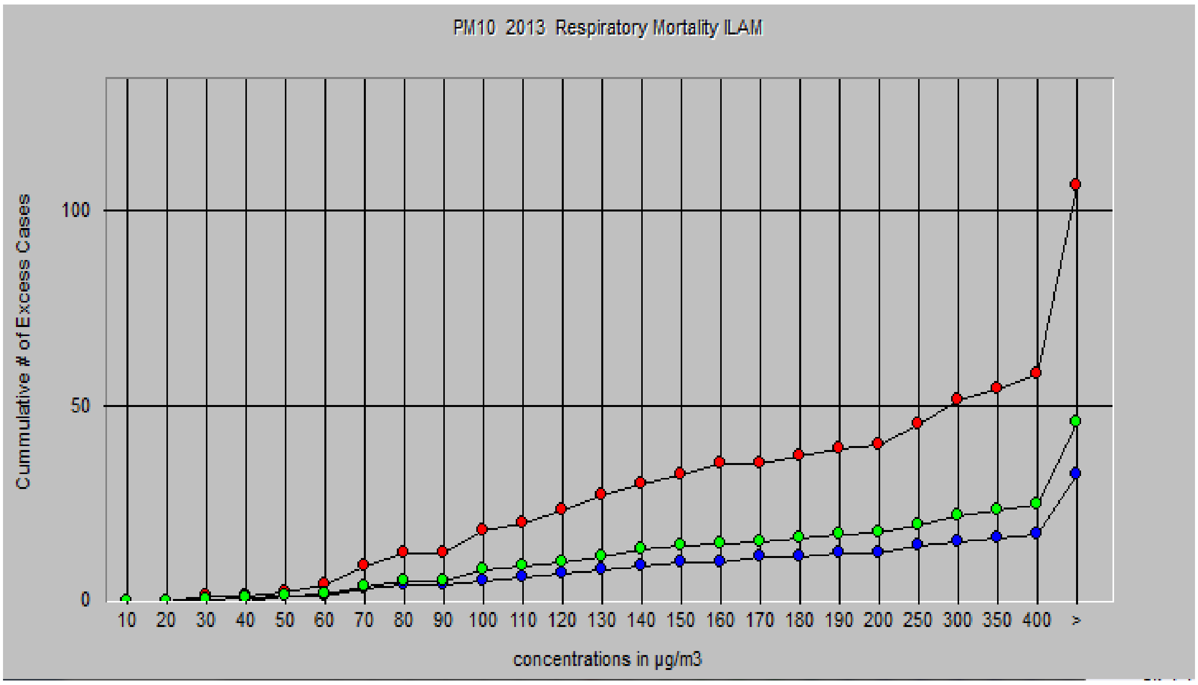

Figure (1): Estimation of cumulative number of respiratory mortality attributed to PM_{10}against concentration intervals in Ilam in 2013

Figure (1) shows that upward trend of respiratory diseases mortality was uniform as PM_{10} increased at concentrationsof 80-180 µg and was fixed at concentration of 190 µg and then suddenly increased as the concentration increased over 200 µg and then by the increase of concentration over 400 µg respiratory mortality increased again suddenly

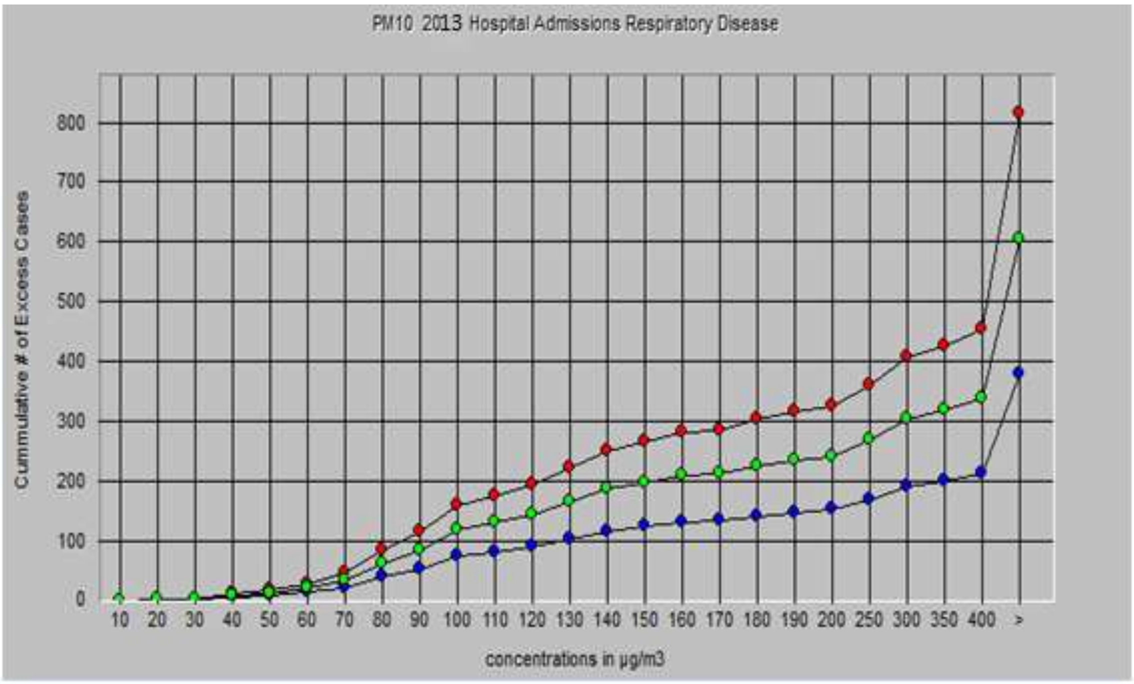

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Figure (2): Estimation of the cumulative number of hospital admissions respiratory diseases attributed to PM10 against concentration intervals in Ilam in 2013

Figure (2) shows that the upward trend of hospital admissions respiratory diseases was uniform as PM_{10} increased at concentration of 80-180 µg and was fixed at concentration of 190 µg and then suddenly increased as the concentration increased over 200 µg and then by the increase of concentration over 400 µg hospital admissions respiratory diseases increased again suddenly.

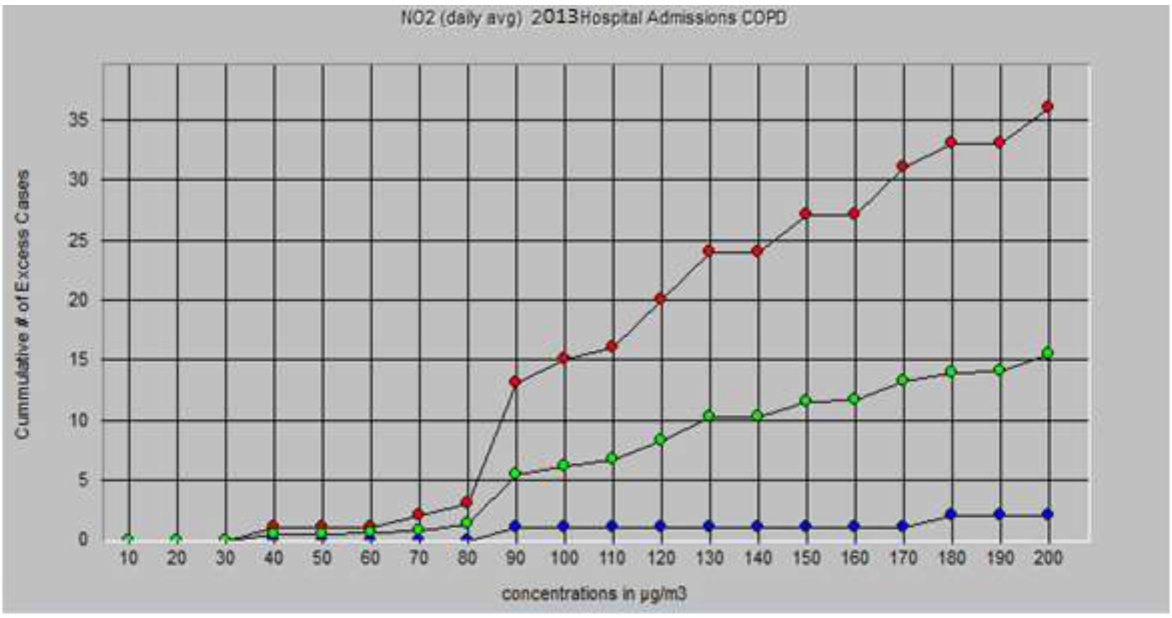

Figure (3): Estimation of the cumulative number of hospital admissions chronic obstructive pulmonary diseaseattributed to NO_2 against concentration intervals in Ilam in 2013

Figure (3) shows that the upward trend of hospital admissions COPD was uniform as NO_2 increased at concentrations 40-70 µg and then suddenly increased at concentration over 80 µg.

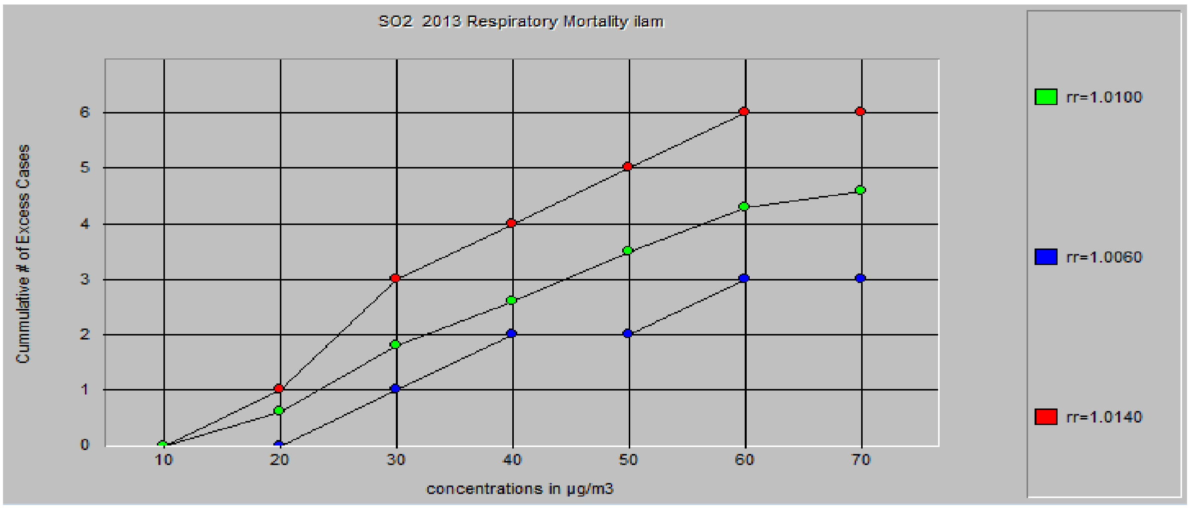

Figure (4): Estimation of the cumulative number of respiratory mortality attributed to SO_2 against concentration intervals in Ilam in 2013

Figure (4) shows that the upward trend of respiratory mortality was uniform as SO_2 increased at concentrations 10-40 µg and then suddenly increased at concentration of 40-50 µg.

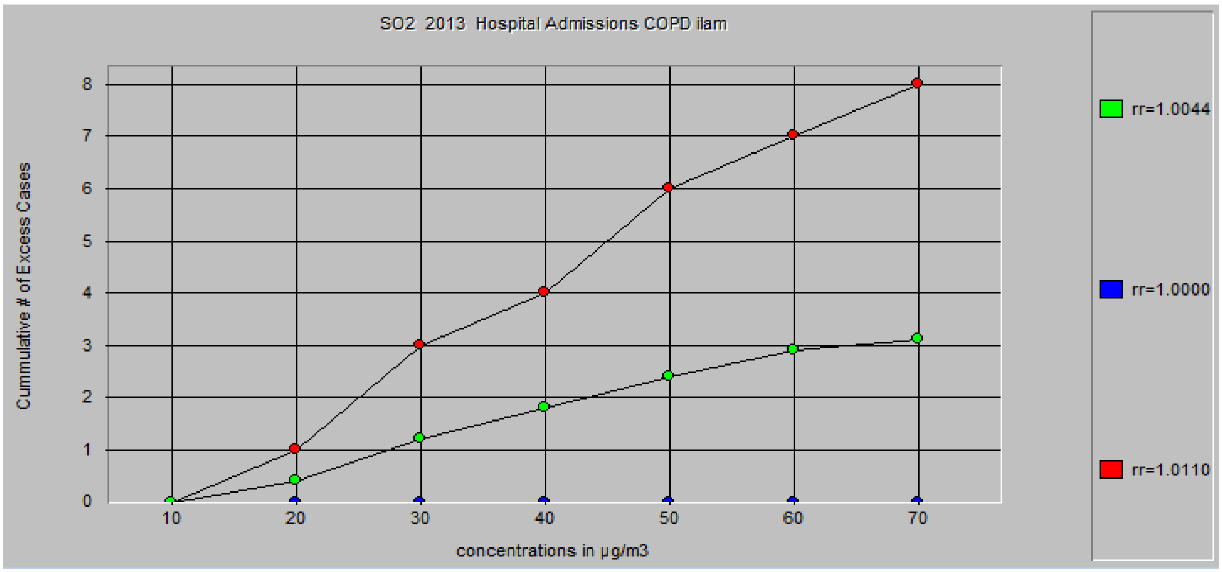

Figure (5): Estimation of the cumulative number of hospital admissions chronic obstructive pulmonary diseaseattributed to SO_2 against concentration intervals in Ilam in 2013

Figure (5) shows that the upward trend of hospital admissionschronic obstructive pulmonary disease was uniform as SO_2 increased at concentrations 10-30 µg and then suddenly increased at concentration of 40-50 µg.

4. Discussion and Conclusion

4.1. Quantification of PM_{10} Effect in Ilam

The results of the measurement in 2012 showed that the annual average concentration of pm_{10}, NO_2, and SO_2 contaminants in Ilam was 330.55, 92.41, and 30.43 µg/m^3, respectively. The annual concentration of PM_{10} in Ilamwas 6 times as much as the annual international air quality standards in Europe (50 µg/m^3), annual concentration of NO_2 was twice as much as the the annual international air quality standards in Europe (40 µg/m^3) and the annual concentration of SO_2 wasless than the annual international air quality standards in Europe (50 µg/m^3) in 2013. With ragrd to the central relative risk of 1.012 or attributed component of 15.14%, the cumulative number of PM_{10} respratory mortality was 46 persons in 2013 in Ilam.56% of the deaths has occurred in days with concentration of less than 400 µg/m^3. The sharp steep of the curve associated with rr=1.012 in Figure (1) indicates the highest number of respiratory mortality (20 persons) in the area at the concentartion of (350-399 µg/m^3). The upper and the lower curves, as shown in the figure, had the highest slope in these two areas. The subtle slope at the concentration intervals of 10-60 µg/m^3 is consistent with the lowest number of respiratory mortality observed in this interval. It is obvious that slight reduction or in other words, the lowest level of the number of respiratory mortality was associated with the sever reduction of percentage of persons per day which in turn indicated the few numbers of the days of exposure or contact with the concentration interval. The cumulative number of respiratory diseases in estmation of middle level of relative risk (1.008) and the basic incidence rate (1260) per 10^5 persons was 605 ones.Approximately, 56% of the cases occurred during the days that the concenttartion of PM_{10} has not exceeded 400 µg/m^3. It should be noted that 606 persons have all been attributed to the exposure to PM_{10}. Accordingly, the number of hospital admissions respiratory diseases attributed to PM_{10} was about 10.63% of the total persons with the same health outcome. The cumulative number of this health outcome at low (1.0048) and high (1.0112) estimatiuons of relative risk was 379 and 813 persons, respectively. For every 10µg/m^3 increase in PM_{10} concentration, the risk of respiratory mortality and hospiral admissions respiratory disease increased 1.2% and 0.8%, respectively.

4.2. Quantification of NO_2 Effect in Ilam

Attributed component in chronic obstructive pulmonary disease was equal to 36.3%. Accordingly, the cumulative number of chronic obstructive pulmonary disease was 15 persons. 85% of the cases occurred at concentrations lower than 170 µg/m^3. On the other hand, there was no exposure at concentrations higher than 200 µg/m^3. Figure (3) shows that in spite of relative risk, the health effect of NO_2 at concentrations lower than 30 µg/m^3 due to the lack of population exposure to the concentrations. In other words, NO_2concentration was never below 30 µg/m^3in Ilam in 2013. For every 10 µg/m^3 increase in the concentration of $NO_2$the risk of chronic obstructive pulmonarydisease increased 0.38%.

4.3. Quantification of Health Effect of SO_2 in Ilam

The relative risk estimated at middle level with low certainty equal to 8.64 (5.37 in CI=0.05 and 11.69 in CI=0.95) meant one percent increase of respiratory mortality risk for the increase of 10 µg/m^3 in SO_2 concentration. Estimated respiratory mortality attributed to SO_2 in Ilam was 5 persons in 2013. According to the attributed component percentage complied with three estimated levels of relative risk, the cumulative number of respiratory mortality was equal to 5 persons (3 persons at rr=1.006 and 6 persons at rr=1.014).relative risk, attributed ratio percentage, and attributed cases to So_2 for chronic obstructive pulmonary disease were estimated.The compliance of low level estimation of relative risk with 1 indicates the lack of effect of risk factor (SO_2) on the development of mentioned health effect. The compliance of lower curve in Figure (5) with horizontal axis indicates this concept. The estimated cumulative number of hospital admissions chronic obstructive pulmonary disease due to exposure to sulfur dioxide was 3 persons. Moreover, few numbers of hospital admissions for this disease is possibly associated with low basic level (101.4 per 100000 people). It is obvious that for every 10 µg/m3 increase in the concentration of SO_2, the risk of respiratory mortality and chronic obstructive pulmonary disease increases 1% and 0.44%, respectively.

The increasing use of vehicles provides the ground for urban development and growth in the field of economy, but it also causesair and noise pollution.Geographical location of Ilam and its being surrounded by altitudes in north, and southwest-northwest route of general currents of air along with the influence of dusty air flows from Iraq in some special times of the year particularly in summer and winter have increased the rate of dust and air pollution in the city of Ilam. Among the factors contributing to air and noise pollution, vehicles have a major role. Most cities with the population of over 100000 people are dealing with air pollution and noise pollution and according to some experts, air pollution and noise pollution form 47% of all the environmental pollutions. Urban traffic volume is closely associated with air pollution and noise pollution, so that as traffic load increases, the rate of air contaminants such as carbon monoxide, burned hydrocarbons, sulfur dioxide, nitrogen oxide will increase. For instance, each vehicle produces about 200 g CO_2 and 6 g NO_2 per km or consumes the oxygen that a person needs to breathe for one year. Moreover, there is a close relationship between the rate of contamination and the type of vehicle and as the average age of vehicles increases, the rate of contamination increases.According to the data published by traffic center in 2006, more than 70000 vehicles are traveling inIlam. Furthermore, according to the conducted tests, 49% of the vehicles in Ilammake pollution more than the standard rate. Heating sources of workshops and industrial units have lower share in Ilam air pollution. Due to topographic conditions and land limitation in the central parts of the city and narrow of streets and mass entrance of vehicles, Ilamis facing long traffic jams and traffic nodes. If the lack of parking space downtown is added to the cited problems, the depth of the problem and the severity of the pollution will be more tangible. Detailed review of city development plan and emphasis on urgent widening of streets and passages downtown and constructing multi-floor parking space, developing shopping centers and services in different parts of the city, accurate study and preparation of comprehensive traffic plan in both short and long terms, preventing the movement of oil vehicles in the city and improving public transportation system are the most important solutions to the reduction of air and noise pollution.

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